trench;

patterning and etching said wiring trench down to the level of the silicon wafer, thereby forming a via hole;

depositing a layer of copper to a thickness sufficient to fill the via hole and to over-fill the wiring trench; and

by means of chemical mechanical polishing, removing copper until said wiring trench is just filled and there is no copper on any exposed surface outside the trench, thereby forming said damascene structure and whereby said damascene structure is free of cracking and peeling.

REMARKS

In light of the above amendments, reconsideration of the rejection of all claims is respectfully requested. We wish to comment on Examiner Vinh's remarks as follows:

Overview:

The present invention teaches a process for preparing a low k film by using PECVD wherein chemical vapor deposition is enhanced by the addition of a gaseous plasma (typically helium). The novel feature of the invention is that power **to the plasma** is arranged to alternate between a low and a high value several times during the deposition

of the same film. Under these conditions, low k films having flat band voltages close to ideal (about 2 volts) are obtained.

Reconsideration is requested of all rejections based on 35 U.S.C. 103:

Re claims 1, 9, and 14, Examiner has based rejection of these claims on three references:

(1) Huang is cited as teaching application of low and high bias powers to the deposition of a low k film. In response to our answer, Examiner concedes that bias power is not the same as power to the plasma but argues that claim 1, as originally written, does not exclude application of bias power. We have, accordingly, amended claims 1, 9, and 14 to explicitly limit the applied power to power to the plasma. A short excerpt from "The Handbook of Thin Film Technology" is included with this response to document the fact that bias power is not the same as plasma power.

(2) Murugesh is cited as teaching alternating steps of depositing the film and then heating it because the claim, as originally written, does not exclude the use of an extra step between the first and second depositions. We find this argument to be very strange indeed. Since there are an infinity of possible steps that our claim does not exclude, Examiner is, in effect, arguing that ANY reference that teaches plasma deposition, along

with at least one other step, reads on our claim. However, rather than continuing to argue the matter, we have amended claim 1 to explicitly state that there are no intervening steps between the deposition of the two types of film.

(3) Cheung et al. are cited as teaching application of low and high power for the deposition of a low k film. Examiner argues that, although the high and low power depositions were used to form different films, the reference still reads on our claims because we teach only that two power levels are successively used for depositing a low k film. This is incorrect. Our claim 1 reads, in part, as follows:

"depositing a first layer of low dielectric constant material by means of plasma enhanced vapor deposition, at a first level of power applied to only said plasma;

then, with no intervening steps, depositing a second layer of the low dielectric constant material..."

Since proper antecedent basis has been provided, it is explicit that the second low k layer is made of the same material as the first low k layer whereas Cheung use low power to deposit black diamond films and high power to deposit FSG films, two different materials.

Additionally, rather than continuing to argue the matter, we have amended claim 1 to explicitly state that there are no intervening steps between the deposition of the two

films so all possibility of using different materials is excluded.

Re claim 8, 13 and 18, Examiner argues that "...since it is known in the art that oxide/low dielectric constant material has a flat band voltage of -1.82 V.....it would have been obvious.....to employ a low dielectric constant material having a flat band voltage that is less than about -3 V to achieve lower leakage current density.".

In our response to the first rejection, we stated that "this argument would be valid if the independent claims on which each of these claims depend were directed to a method for achieving low leakage current density. But said independent claims teach a process to form a layer of low k material, a layer of black diamond, and a damascene structure (that includes a low k film). Claims 8, 13, and 18 narrow these claims to a process to form a layer of material having a flat band voltage that is less than about -3 V. The fact that an invention teaches how to make something that can be imagined but for which there previously existed no known process for its manufacture, does not make said process obvious.".

Examiner has nor responded to these arguments. We respectfully request that he please do so or, preferably, now allow these claims.

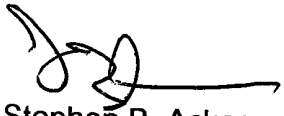
In conclusion, we again thank Examiner Vinh for his ongoing examination of our

application.

Reconsideration and withdrawal of the rejection is respectfully requested.

Allowance of all Claims is requested. It is also requested that should Examiner Vinh not find that the Claims are now Allowable, he should please call the undersigned Attorney at (845)-452-5863 to overcome any problems preventing Allowance.

Respectfully submitted



Stephen B. Ackerman #37761

VERSION WITH MARKINGS TO SHOW CHANGES MADE

In the claims:

Please amend the following claims:

1. A process for forming a layer of low dielectric constant material having a predetermined thickness, comprising:

depositing a first layer of low dielectric constant material by means of plasma enhanced vapor deposition, at a first level of power [level] applied to only said plasma;

then, with no intervening steps, depositing a second layer of the low dielectric constant material by means of plasma enhanced vapor deposition, at a second power level, a pplied to only said plasma, that is higher than said first power level; and

repeating the preceding two steps until the predetermined thickness is reached.

9. A process for depositing a layer of black diamond on a silicon wafer to a predetermined thickness, comprising:

through chemical vapor deposition, from a first gaseous mixture of methyl silane and nitrous oxide, enhanced by a helium plasma at a power level to only said plasma that is less than about 70 watts, depositing a low power layer of black diamond for about 10 seconds, thereby forming a layer having a thickness between about 700 and 1,000

Angstroms;

then through chemical vapor deposition, from a second gaseous mixture of methyl silane, nitrous oxide, and oxygen, enhanced by a helium plasma at a power level, to only said plasma, of between about 70 and 200 watts, depositing onto said low power layer a high power layer of black diamond for about 10 seconds, thereby forming a layer having a thickness between about 700 and 1,000 Angstroms; and

repeating the preceding two steps until said predetermined thickness is reached.

14. A process for forming a dual damascene structure on a silicon wafer, comprising:

through chemical vapor deposition, from a first gaseous mixture of methyl silane and nitrous oxide, enhanced by a helium plasma at a power level, to only said plasma, that is less than about 70 watts, depositing a low power layer of black diamond for about 10 seconds, thereby forming a layer having a thickness between about 700 and 1,000 Angstroms;

then through chemical vapor deposition, from a second gaseous mixture of methyl silane, nitrous oxide, and oxygen, enhanced by a helium plasma at a power level, to only said plasma, of between about 70 and 200 watts, depositing onto said low power layer a high power layer of black diamond for about 10 seconds, thereby forming a layer having a thickness between about 700 and 1,000 Angstroms;

repeating the preceding two steps until a completed black diamond layer has been

formed;

patterning and etching said completed black diamond layer in order to form a wiring trench;

patterning and etching said wiring trench down to the level of the silicon wafer, thereby forming a via hole;

depositing a layer of copper to a thickness sufficient to fill the via hole and to over-fill the wiring trench; and

by means of chemical mechanical polishing, removing copper until said wiring trench is just filled and there is no copper on any exposed surface outside the trench, thereby forming said damascene structure and whereby said damascene structure is free of cracking and peeling.

(depending on the overall state of the system) must be expected during which these impurities will be present. After a time period has elapsed which experience has shown to be sufficient for these internally generated impurities to be down to insignificant levels, the shutter can be opened. A similar function is served by the shutter with respect to impurity gases initially present at or near the surface of the cathode.

The first description of a getter-sputtering apparatus appears to have been published in 1943 by Berghaus and Burkhardt,[68] whose equipment was remarkably similar to that shown in Fig. 15. More recently, getter sputtering has been developed as a film-deposition technique by Theuerer and Hauser, who have also described a number of different versions of getter-sputtering equipment.[69,70] They have been primarily interested in superconducting materials and have been able to deposit films of materials such as niobium and tantalum with critical temperatures which agree well with the accepted bulk values.

c. Bias Sputtering and Asymmetric AC Sputtering

It was discussed in an earlier section that films being deposited by sputtering may be subject to a certain amount of resputtering. This occurs either through the action of energetic neutrals, negative ions that originate at, or near, the cathode, or in the case of insulating films, because positive ions may have been accelerated toward the film surface as a result of a significant negative floating potential there. If, instead of leaving its potential to chance, the film is deliberately given a negative potential with respect to the plasma, the resulting technique is referred to as bias sputtering.[71,72]

The basis for expecting bias sputtering to lead to films of higher purity is that, during resputtering, most impurities should be preferentially removed relative to the atoms of the main film. Whether or not this will occur depends on the relative strengths of the metal-to-impurity and the metal-to-metal bonds. Thus, for example, as a means for removing oxygen from sputtered films, bias sputtering is very effective for materials such as tantalum, molybdenum, and niobium but has little effect for materials such as aluminum and magnesium in which the oxide bond is stronger than the metallic bond.

The first description of an apparatus in which the substrate is given a negative bias with respect to the anode in order to improve film purity appears to have been given by Berghaus and Burkhardt.[73] However, they mistakenly thought that the improved properties exhibited by their films were a consequence of the additional heating of the film by the ion bombardment. A description of a bias-sputtering apparatus for improving the epitaxial growth of germanium films was given by Wehner[24] in 1962, while a detailed analysis of the processes occurring during bias sputtering (with particular reference to tantalum) was provided by Maissel and Schaible[74] in 1965. In the latter publication it was shown that (2) is modified in the presence of bias to

$$f_i = \frac{\alpha_i N_i - (j/q)(AS - \beta)}{\alpha_i N_i - (j/q)(AS - \beta) + R}$$

where

$$A = \frac{\alpha_i N_i + \beta j/q}{\alpha_i N_i + j(S + \beta)/q}$$

and β is the fraction of the bias current due to impurity ions, j is the bias current density, q is the electronic charge, and S is the sputtering yield for the impurities.

The results of this theory are compared with experiment in Fig. 16, while in Fig. 17 are shown the effects of bias against different background levels of impurity. The increase in impurity concentration at very low bias is not quantitatively understood at this time; however, the very rapid falloff in impurity concentration to the right of the peak at approximately 20 V is believed to represent the onset for sputtering of the impurities out of the tantalum. The increase in resistivity at high bias voltages is believed to be due to an increase in the concentration of trapped argon and will be discussed in the next section.

While bias has a pronounced effect on the impurity content of sputtered films, it can also exert an influence on their structure. The influence of bias on the structure of

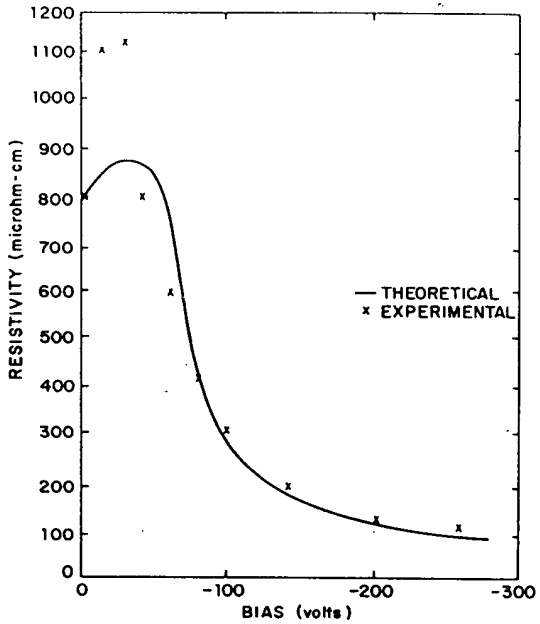


Fig. 16 Resistivity vs. bias voltage for tantalum films comparing theory with experiment

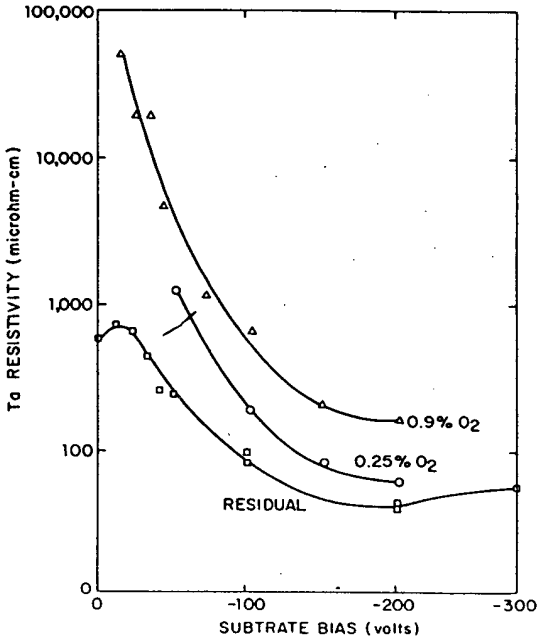


Fig. 17 Resistivity of tantalum films vs. bias for several levels of oxygen contamination during deposition.

Handbook of Thin Film Technology

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